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CHOOSING A SIMILARITY INDEX TO QUANTIFY GAIT DATA VARIABILITY

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INTRODUCTION

Repeatability and reproducibility of joint kinematics can be assessed through Similarity Indices (SI) quantifying their pattern variability. These include: Coefficient of Multiple Correlation (CMC) [1]; Mean Absolute Variability (MAV) [2]; and Linear Fit Method (LFM) [3], which accounts for scaling (a_1), offset (a_0) and truthfulness of the linear model between the curves (R^2). Among gait cycles, the intra-subject variability for a given joint is due to physiological fluctuations of the range of motion (ROM) and time shift. SIs might be differently affected for each joint, due to their different ROMs, and by marker positioning, leading to offsets among gait curves. This paper aims to investigate the effects that each of these sources of curve variability has on the SIs, in order to provide indications on which is the most suitable for the assessment of gait similarity.

METHODS

Four groups of simulations were conducted to study the influence of each variability source on CMC, MAV and LFM coefficients, which were calculated on datasets composed by five synthetic curves [4]:

$$k(t) = O + \frac{1}{2}\left(ROM \pm \frac{A}{2}\right)\left[0.5\sin\frac{2\ (t\ )}{100} + 0.5\sin\frac{4\ (t\ )}{100}\right],\ \ t \in [0,100]$$

One variability source per time varied within each group of simulations, and across different datasets, specifically: (i) ROM (values: 5, 10, 20, 40, 60°); (ii) ROM fluctuation ($\Delta A_{\%}$; values: 5, 10, 15, 20, 25, 30%$_{ROM}$), i.e. the percentage difference between maximum and minimum ROMs, normalized on the ROM averaged among strides; (iii) offset (O, values: 10, 40, 70, 100, 130, 160, 190%$_{ROM}$); (iv) time shift (τ, values: 5, 10, 15, 20%$_{GaitCycle}$). A ROM equal to 5° was set for cases (ii)-(iv). The criteria adopted to choose the previously mentioned ranges of variation was based on the lowest and the highest variability values obtained from gait data of the lower limb of ten healthy subjects [5].

RESULTS

CMC was always >0.99 for different ROMs, and was the least sensitive to variations of ROM fluctuation (>0.99 for all levels, except for $\Delta A_{\%}$=30%$_{ROM}$ with CMC=0.99). CMC decreased from >0.99 to 0.44 when O increased from 10%$_{ROM}$ to 190%$_{ROM}$, and decreased from 0.98 to 0.73 when τ increased from 5%$_{GaitCycle}$ to 20%$_{GaitCycle}$.

MAV increased when each source of variability increased: from 0.1° to 1.2° for ROM in the range of 5-60°; from 0.1° to 0.6° for $\Delta A_{\%}$ in the range of 5-30%$_{ROM}$; from 0.5° to 9.5° in the range of 10-190%$_{ROM}$; from 1.1° to 3.8° for τ in the range of 5-20%$_{GaitCycle}$.

LFM was insensitive to different ROMs (a_1=1.00 ± 0.02, a_0=0.00 ± 0.00°, R^2=1.00 ± 0.00 for all levels), whereas $\Delta A_{\%}$, O and τ affected a_1, a_0, and R^2, respectively: a_1 varied from 1.00 ± 0.02 to 1.00 ± 0.10 for $\Delta A_{\%}$ ranging from 5 to 30%$_{ROM}$, with a_0=(0.00 ± 0.00)°, R^2=1.00 ± 0.00; a_0 ranged between (0.00 ± 0.2)° to (0.00 ± 3.8)° for O varying from 10%$_{ROM}$ to 190%$_{ROM}$, with a_1=1.00 ± 0.00 and R^2=1.00 ± 0.00; a_1 varied from 1.00 ± 0.02 to 1.00 ± 0.23, and R^2 from 0.97 ± 0.02 to 0.64 ± 0.28 for τ varying from 5%$_{GaitCycle}$ to 20%$_{GaitCycle}$ with a_0=(0.00 ± 0.2)°.

DISCUSSION

MAV showed no specialised behaviour with respect to the source of variability so it was not able to detect the leading cause for the variability among curves. CMC was not sensitive to ROM and, among the chosen indices, was the least sensitive to $\Delta A_{\%}$. CMC decreased, instead, when τ and O increased, requiring further analysis to separate these two effects. Whereas, a_1, a_0, and R^2 were not sensitive to ROM, and are affected by $\Delta A_{\%}$, O and τ, respectively. Thus, the results suggest using the LFM to assess gait data similarity, as it performs a more complete analysis on the data.

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